Harmsworth's
Wireless Encyclopedia

THE marked popularity of Wireless, since modern improvements enabled speech and music to be transmitted by means of ether waves, has brought into existence a great mass of publications, and has led to the dissemination of a variety of miscellaneous information connected with the subject, about both principles of theory and details of practice. The time has come when a comprehensive work of reference is required, so that special points can be looked up with a minimum of trouble. Fortunately, the amateurs who have taken up Wireless as a hobby are not content with merely listening-in and making demonstrations to their friends and relatives; they want to understand more seriously the principles underlying this great and remarkable development of human powers of communication.

SPEECH used to be limited to persons within audible range. Now it can be distributed broadcast over an Empire. This constitutes a new responsibility, like every other newly acquired power; but it is difficult to foresee any base uses to which it can be applied. It is one of the few inventions which seem wholly beneficial; and the amount of interest in it is to be heartily welcomed.

CONSEQUENTLY, when asked to contribute and to be consulted about HARMSWORTH'S WIRELESS ENCYCLOPEDIA, I felt, after seeing some proof-sheets and the wealth of illustration contemplated, and the general completeness with which it was being prepared, that I could legitimately devote some portion of my very limited time to assist in some minor degree, in a consultative capacity, those whose practical knowledge makes them familiar with the most recent developments, and who had been asked to join in producing a book which aimed at giving a widespread knowledge, to some extent of the principles, and to a still larger extent of the details, of its many branches. It must be understood that I am not responsible for all the contents of the different articles; that responsibility must rest upon the writers.

I HOPE that the publication will meet with the circulation it deserves; and in this broadcast manner I convey to my unknown friends who are enthusiastic about Wireless my cordial good wishes, accompanied by an expression of admiration for the scientific and technical skill which has developed this modern outcome of physics and engineering from what it was in 1897—when, in supplement to Mr. Marconi's initial enterprise, I took out my fundamental Patent for Tuned or Selective Wireless Telegraphy—to what it is now in 1923, the interval being surely one of the most prolific quarter-centuries, both for good and for evil, in the entire history of mankind.

Oliver Lodge

Sir Oliver Lodge in His Laboratory

From a camera portrait by E. O. Hoppé

Wireless and Other Waves

by SIR OLIVER LODGE, F.R.S., D.Sc.

Author of "Modern Views of Electricity," "The Ether of Space," etc., inventor and pioneer in wireless telegraphy

Our distinguished contributor and Consultative Editor explains concisely in this contribution the extraordinarily interesting relations between all types of ether waves, of which light, X-ray and wireless waves are similar in character, differing but in length

WAVES and the vibrations which give rise to them, and by which we are enabled to perceive them, contribute a great deal to our knowledge of the world and of the universe. It is through waves of light that we gain a knowledge of the stars, even of their chemical composition and velocities, and of the existence of other worlds in space. Without the information thus acquired our universe would shrink to the small planet which we occupy.

It is through waves of sound, also, that we are able to communicate with each other, and to hear events which are occurring at a distance. Without these two sources of information we should be limited to what we could touch and smell and taste. The two main senses of man are dependent on waves or tremors—that is, on vibrations of some kind.

But now we have to consider in what sense the term "wave" can be applied to sound or to light. The term wave was originally used, no doubt, to signify the travelling humps on the sea and the ripples on smaller pieces of water. And it was by no means obvious—it had to be discovered—that there was any analogy between them and the apparently quite distinct phenomena of sound and light.

Simple Mathematics of Waves

AS a matter of fact the waves are very different; and it is chiefly because they can all be represented by the same mathematical equation that the same term is applicable to such very different phenomena.

Ask a mathematician what he understands by a wave, and he will probably reply $\frac{d^2y}{dt^2} = v^2 \frac{d^2y^2}{dx^2}$. And if asked to put this into words, he would say: Something periodic both in space and time, travelling in the direction x with the velocity v. Let us illustrate this.

By "periodic" is meant repetition at regular intervals. A row of railings is periodic in space, if the railings are all exactly alike. The swing of a pendulum is periodic in time. And if you had a row of pendulums swinging in regular succession, not all swinging together but started one after the other, the arrangement would be periodic in both space and time; and if you watched the pendulum bobs you would see a wave form running along them, coming in apparently at one end and going out at the other. There is no real progressive motion of anything material, but there is a form which progresses.

One might take another analogy. The turns of a corkscrew are periodic in space. If you make it revolve it is periodic in time, too; and accordingly you see the waves advancing.

How the Wave Form Progresses

SO it is on the open sea. The wave advances, but the particles do not. The particles heave up and down. But because they do it in regular and periodic order the result is an apparent progression, which anyone can see by throwing a pebble into a pond. Near the shore the waves get more complicated. The bottom part is held back by the beach, the top part travels forward, and the wave topples over and breaks upon the shore. These also are popularly called waves, but they are more complicated than true waves.

They are breaking waves, and represent absorption or destruction of the wave motion, and its conversion into the irregular vibration which appeals to our senses as heat; though indeed the heat thus generated hardly raises the temperature of the water appreciably unless the waves are exceedingly violent. Nevertheless, that is the way we get heat from the sun. The energy does not come to us as heat. It comes to us as some form of

wave motion, and only when absorbed or quenched by matter does it turn into what we speak of as radiant heat. It is those waves which keep the earth warm, and make vegetation, and life generally, possible. We are *not* dependent on the interior heat of the earth.

Waves are often generated by the molecular agitation we call heat ; and they excite the same kind of agitation when they are received and quenched.

Sound Waves Change to Heat Waves

WAVES of sound also turn into heat when they are absorbed. But if either of these two classes of wave fall upon appropriate receiving organs, they excite the nerves with which those organs are supplied, and thereby give us the sense of sound or of light. How they do this is partly understood and partly still mysterious. The translation of a tremor into a sensation has to be interpreted, as far as it can be interpreted at present, by the science of Psychology.

The eye and the ear only respond to a certain range of tremor. They will not respond to vibrations which are too slow, nor, again, to those which are too quick. The ear has the greater range of the two. The range of the eye is very limited ; the most rapid vibrations which the eye can perceive are only double as quick as the slowest which it can perceive. The slowest excite the sensation that we call red, the most rapid excite the sensation that we call violet.

The Immense Range of Unseen Rays

BUT beyond the violet there is an immense range of ultra-violet, right away up to the X-rays, and, even higher than those, the gamma rays of radium, thousands of times more rapid than anything that can affect the eye. Fortunately, however, they are able to affect certain chemicals, and therefore can be photographed. Below the red, again, there is a great range, which is called infra-red ; and, very much slower than that series of ether pulsations, the waves which are used in wireless telegraphy. These can neither be seen nor photographed ; we require special instruments for their detection. They are big things, they require a big collecting apparatus, well known as "the aerial," and that has to be associated with either a coherer or a crystal or a vacuum valve, which has the property of rectifying them and enabling them to produce electric or magnetic effects, so that they can deflect a galvanometer or be heard in a telephone.

So far we have dealt with the analogy between the different forms of wave. We must now say a word about their differences. Waves of the sea and ripples only occur on the surface of a liquid. They are a very special, though a familiar, type.

No Sound Waves Without Air

WAVES of sound are not really appreciable as waves at all. They consist of compressions and rarefactions of the air, periodic variations of pressure, such as might cause vibrations in a drum-skin or any other flexible instrument susceptible to rapid changes of pressure. Such a drum-skin is provided in the ear, and, by what we must call ingenious mechanism, is transmuted into forcible though minute vibrations which can affect the endings of the auditory nerve.

Without air there would be no sound ; it is conveyed by matter, and the ear is specially contrived to pick up vibrations from a gaseous medium. Sound can be transmitted by solids and liquids also, but always by some form of matter. In that it differs entirely from light. The air is no assistance to light ; it can travel perfectly well in a vacuum. Air, and aqueous particles suspended in the air, are obstructive to light rather than helpful.

How Light Waves Travel in Space

IF light is not conveyed, then, but rather obstructed by matter—which is liable to absorb and quench it and turn it into heat—if it is able to travel quite freely and unobstructively through vacuum, what is there in that vacuum to convey it ? There clearly must be something : we cannot imagine vibrations in empty space. We have every reason to know that space is not empty, but is filled with a subtle impalpable medium, which used to be called the luminiferous ether—that is to say, a substance which had the power of conveying light. This fact was known more than a century ago ; but since then many other functions of the ether have been discovered, especially those

associated with the terms electricity and magnetism.

But we have no sense organ for their appreciation, we can only investigate those things by instruments. And we have thus learnt that what we call "light" is not a material but an electrical vibration, and that the ether is able to transmit every kind of vibration at the same rate, a rate which has been measured, and amounts to about 186,000 miles per second.

Light and Radio Waves at Same Speed

THE rate at which light travels carries it a distance equal to seven times round the world in a second. A thread wrapped nine times round the world, and then stretched out straight, would reach to the moon, and $1\frac{1}{4}$ seconds is the time taken to cover that distance. This is the rate at which wireless waves travel, for they, too, travel through the ether; and consequently reach every part of the earth that they reach at all in a very minute fraction of a second. So that when it is said that a speaker whose utterances is being broadcasted can be heard by the listeners-in before his voice can reach other people at the back of the same hall as himself, the statement is quite true, and would be true even if the listener-in was a thousand miles away.

In contrasting sound-waves with water-waves, we realise that the motions are very different, and that the rapidity of vibration is different, too. The up-and-down motion on the sea may take several seconds to complete each period. The vibrations of an ordinary voice may be two or three hundred per second, or for a soprano might run up to two or three thousand a second. Indeed, the highest audible squeak is estimated at about forty thousand.

750,000 Vibrations per Second

BUT wireless oscillations are usually more rapid than that, unless the sending station is a gigantic one emitting waves several miles in length. The most usual waves employed in broadcasting are, let us say, about 400 metres, about a quarter of a mile, and the aerial at such a station has to vibrate electrically three-quarters of a million times a second. No form of matter is able to transmit waves at this rate. We are dependent wholly on the properties of the ether for all optical and wireless phenomena. And were it not for the fact that the speed of transmission for every length of wave—whether they be twelve miles, or the millionth of an inch, in length—is accurately the same, there would be great confusion, and the transmission of wireless telephonic speech would be impossible.

The question must now be asked: If waves on water and waves of sound, though both conveyed by matter, differ so entirely in their details—one being a heave up and down, while the other is a to-and-fro compression—what sort of motion is it which occurs in the ether, and what kind of waves are light-waves?

How Does the Ether Transmit Waves?

THE answer at present is that we do not precisely know. We know that they are not like water-waves, nor are they the least like sound-waves. They are purely electric or electro-magnetic. There is something in the structure of the ether which enables it to transmit these peculiar waves, but what the structure of the ether is has not yet been worked out. The remarkable thing is that these electric or ether waves, even if very intense—and they may easily be emitted with the strength of some horse-power—do not affect any of our senses, and do not appear to affect the human organism at all.

Immersed in Speech and Music

WE can live in the midst of them and know nothing about them. As a matter of fact, we are living in the midst of them now, and we can only detect their presence if we provide ourselves with a suitable "medium" for their detection—that is, a suitable receiving instrument. Then we find that we are immersed in speech and music and Morse code, without the least knowledge on the part of ordinary humanity. Only the enlightened experimenter has learnt how to receive these ethereal pulsations and interpret them in the way intended by the sender. There may be many other things in the universe of which we are equally unconscious, and until our eyes are opened, figuratively, or until we are provided with the necessary receiver, we may live and die in complete ignorance of much that is going on round us.